On modeling Arctic sea-ice age and the recent Multi-Year ice decline: 2000-2009

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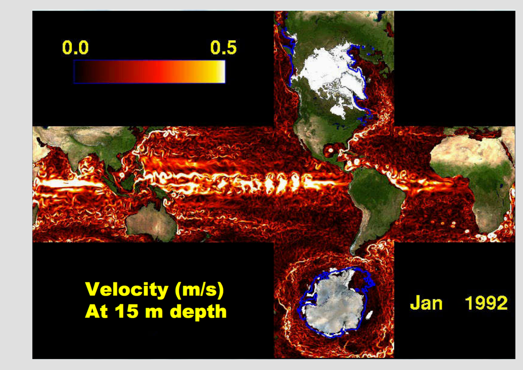
1. Project Objectives:

(i) Implement **a new package in the MITgcm** code **to track sea-ice and snow passive tracers** such as age, salt, biological species, chemical compounds …

(ii) Focus on **reproducing the recent Multi-Year (MY) ice decline** as observed from satellite data since 2000

(iii) Find out **the main physical processes involved in the recent Arctic sea ice volume loss** by understanding the **most important mechanisms acting on the different ice types** (and in particular by weighting the relative importance of export versus thermodynamics processes)

2. ECCO2 regional model configuration:



Ocean model:

- 9-km horizontal grid spacing, 50 vertical levels
- Volume-conserving, C-grid
- Bathymetry: S2004 blend of GEBCO and Smith and Sandwell [1997] [Marks and Smith, 2006]
- KPP mixing [Large et al., 1994]
- BCs from the global optimized solution

Sea-ice model:

- C-grid
- Multi-categories zero-layer thermodynamics [Hibler, 1980; Fenty et al., in prep.]
- Viscous plastic dynamics [Hibler, 1979]
- Prognostic snow and sea-ice salinity

Model parameters:

taken from Nguyen et al. 2011 (see table 2)

Atmospheric forcing:

JRA-25

Simulation:

Duration: 1979-2010

Table 2. Model Parameters Used in Baseline **A0**, Optimized **A1**, and AOMIP Experiments

Parameter	A0	A1	AOMIP[a]	Comment
Initial conditions	ECCO2	WOA05		Fields considered include PHC, WOA05, WOA01, WGHC
Atmospheric forcing	ECCO2	JRA25		ECCO2 was based on ERA40/ECMWF
Ocean albedo	0.15	0.16 ± 0.04	0.10	
Sea ice dry albedo	0.88	0.7	0.6–0.75	0.73–0.83 from the Community Climate System Model (CCSM)[b]
Sea ice wet albedo	0.79	0.71 ± 0.08	0.5–0.68	≥0.655 from CCSM 0.4–0.6 from *Curry et al.* [2001]
Snow dry albedo	0.97	0.87 ± 0.10	0.80–0.84	0.96 from CCSM 0.84 from *Curry et al.* [2001]
Snow wet albedo	0.83	0.81 ± 0.10	0.60–0.77	≥0.86 from CCSM 0.77 from *Curry et al.* [2001]
Ocean/air drag	1.02	1.00 ± 0.05		
Air/sea ice drag	0.0020	0.0011 ± 0.0003	0.0011–0.0013	
Ocean/sea ice drag	0.0052	0.0054 ± 0.0001	0.0055	
Ice strength P^*	2.7	2.3 ± 1.2	1.0–2.75	10^4 Nm^{-2}
Lead closing H_o	0.5	0.6 ± 0.7	0.25–0.5	
Vertical diffusivity	10^{-5}	5.44×10^{-7}		m^2/s
Salt plume	off	on		*Nguyen et al.* [2009]
River runoff factor	1	1.2 ± 1.2		factor × ARDB[c]

[a] *Martin and Gerdes* [2007] and *Johnson et al.* [2007].
[b] Arctic Runoff Database and P. Winsor (personal communication, 2007).
[c] Community Climate System Model, version 3 [*Briegleb et al.*, 2004]. Values listed for spectrum with wavelengths <0.7 μm and are typically ~0.3 higher than those in with wavelengths >0.7 μm.

3.1 Results: Model versus Observations

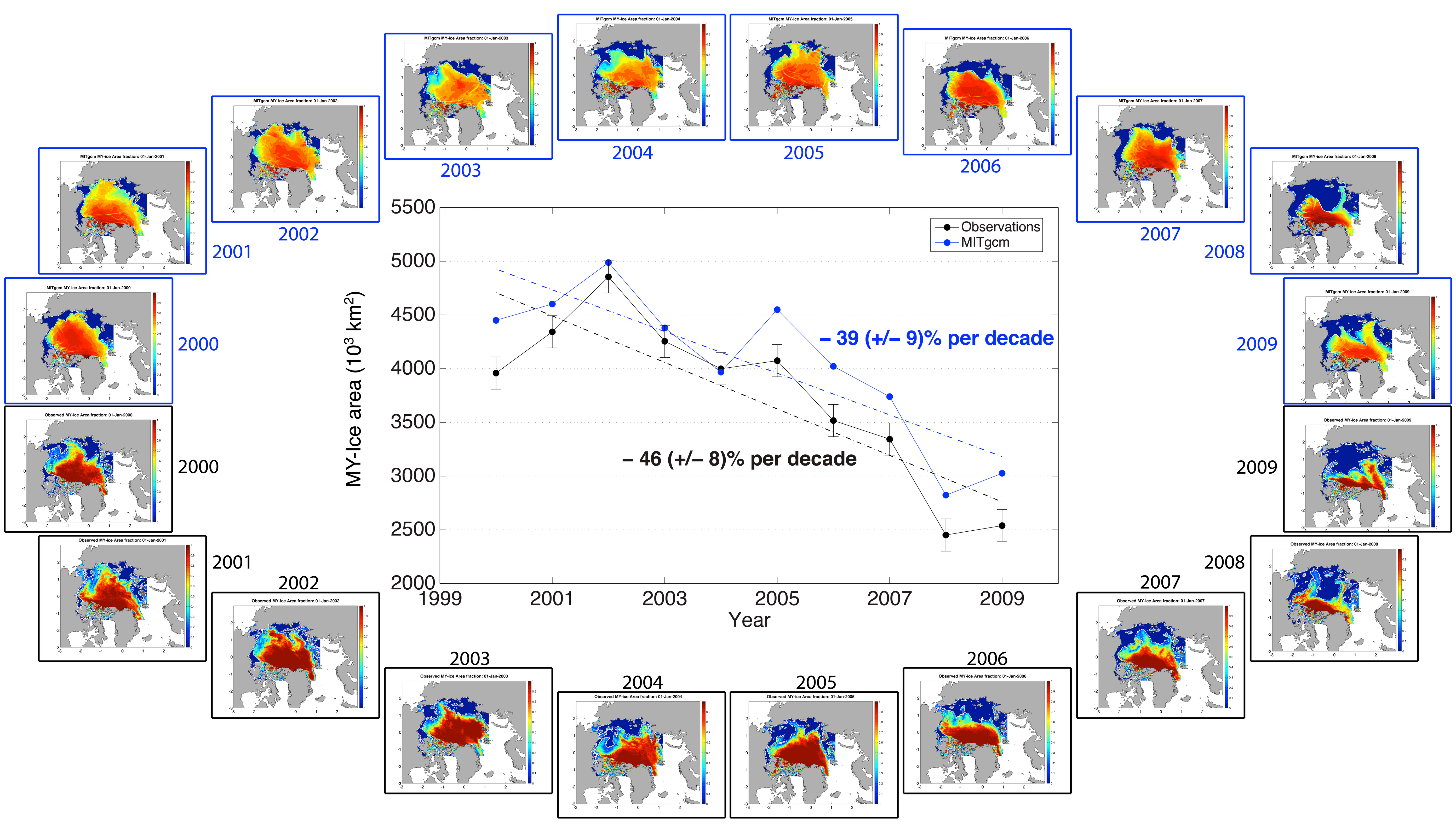


Figure 1. Observed (Black) and modeled (blue) MY sea ice area on January 1st for the period 2000-2009. The amount of MY ice area, the inter-annual variability and the negative trend are all well captured by the simulation. However, some differences remain, for example in terms of spatial repartition of the MY ice.

3.2 Results: Focus on January 2008

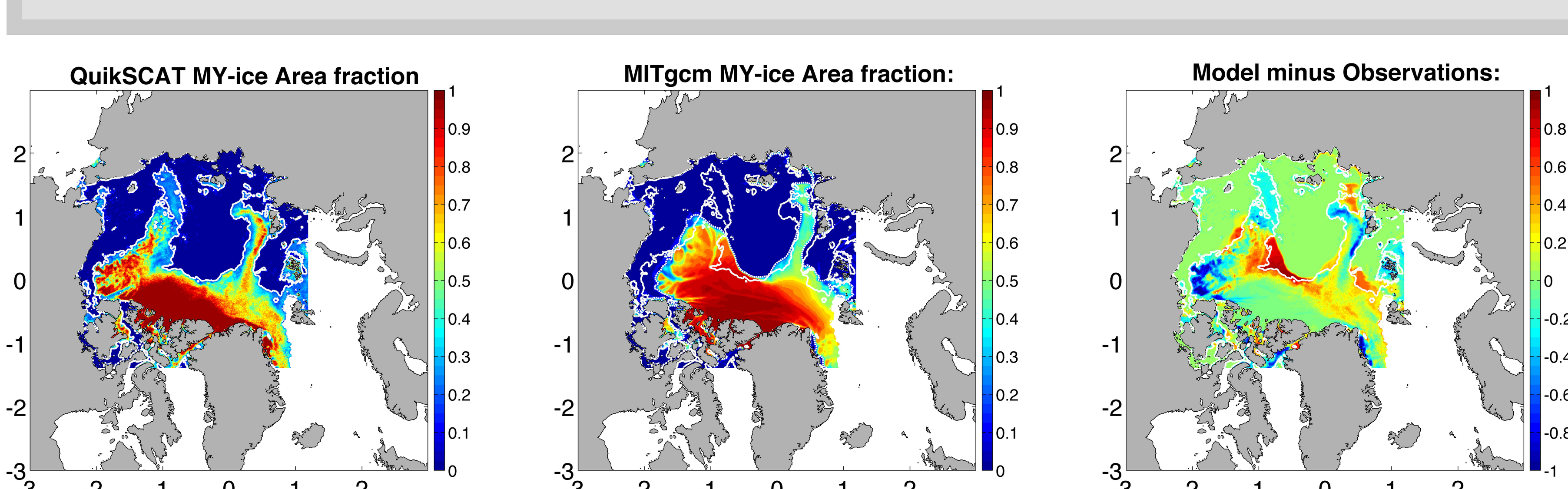


Figure 2. Observed (left) and modeled (middle) multi-year (MY) sea-ice area fraction over the Arctic Ocean on January 1st 2008. Right panel shows the difference (model minus observations). The white line shows QuikSCAT 0.1 MY fraction isopleth. The dashed white line in the middle panel represents this same isopleth for the model. The general pattern is reasonnably reproduced in the model, with the high concentrated MY ice cover located north of Greenland. In addition, the tongue of MY ice crossing the central Arctic from the North of Greenland to the Laptev Sea is remarkably well reproduced. Model's discrepancies are significant in the Beaufort sea and in the central Arctic.

4. Results: MY ice loss contribution to the sea-ice decline

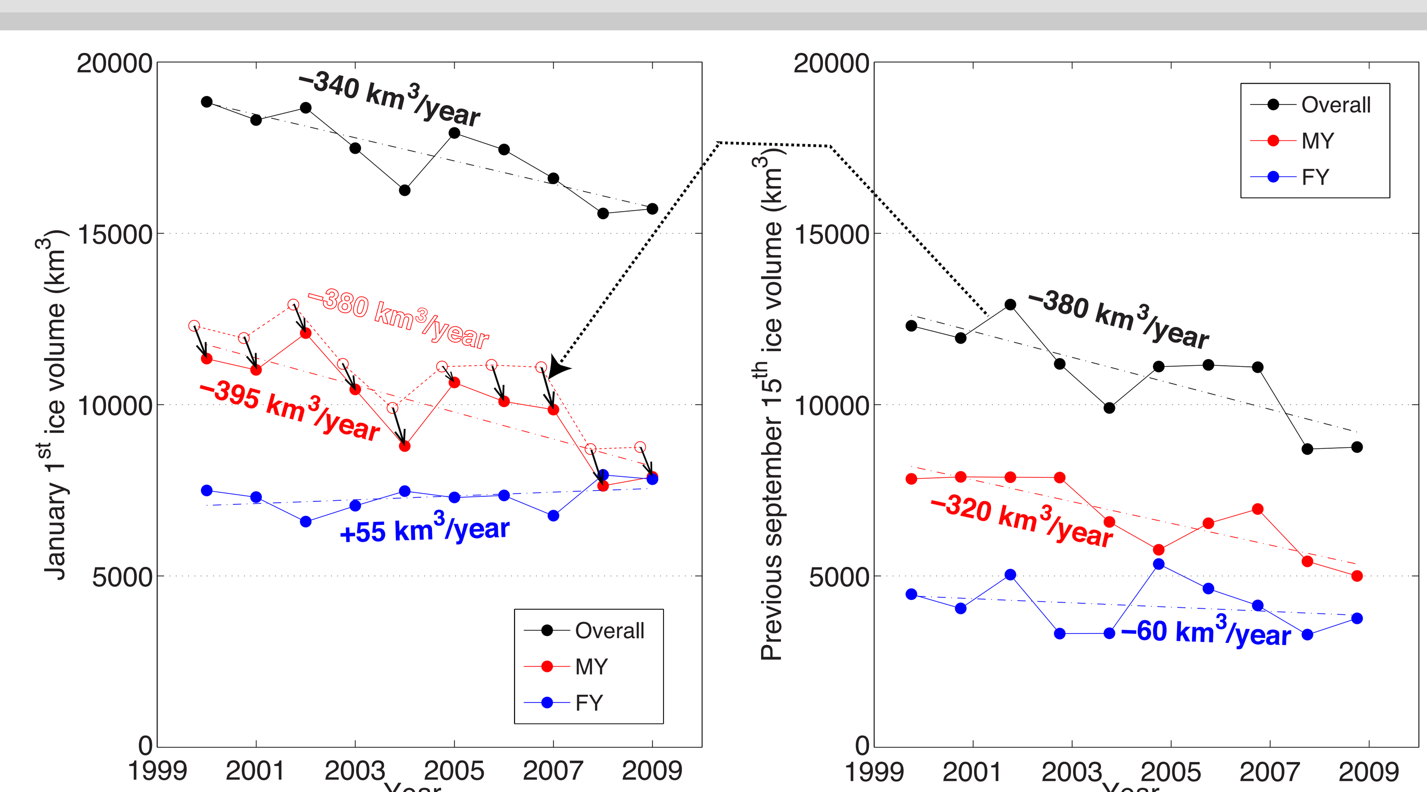


Figure 3. Modeled ice volumes on the 1st of January (left) and the previous 15th of September for the period 2000-2009. In the model, the MY ice volume loss over this period seems to contribute largely to the total volume loss, in accordance with the observations of Kwok et al. 2009. The trend of the FY ice (left panel) is slightly positive (i.e. 55km^3/year), and can be explained by an increase of ice-free surface at the end of the melting season over the same period. The negative trend of the total ice volume at the end of the melting season (right panel, in black) is smaller than that at the beginning of the following winter (left panel, in red). This means, if one considers the net melting to be negligible between September 15th and January 1st, that the export of MY ice has slightly increased on average over the period (left panel, black arrows).

References:

Nguyen et al. (2011), Arctic ice-ocean simulation with optimized model parameters: Approach and assessment, J. Geophys. Res., 116, C04025, doi:10.1029/2010JC006573.

Kwok, R. et al. (2009), Thinning and volume loss of the arctic ocean sea ice cover: 2003-2008. J. Geophys. Res., 114, C07005, doi:10.1029/2009JC005312.

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